



**Jet Propulsion Laboratory**  
California Institute of Technology

# Stanford meeting

## Technology Testbed Status Update

Joon Seo, Testbed team  
22 May 2019



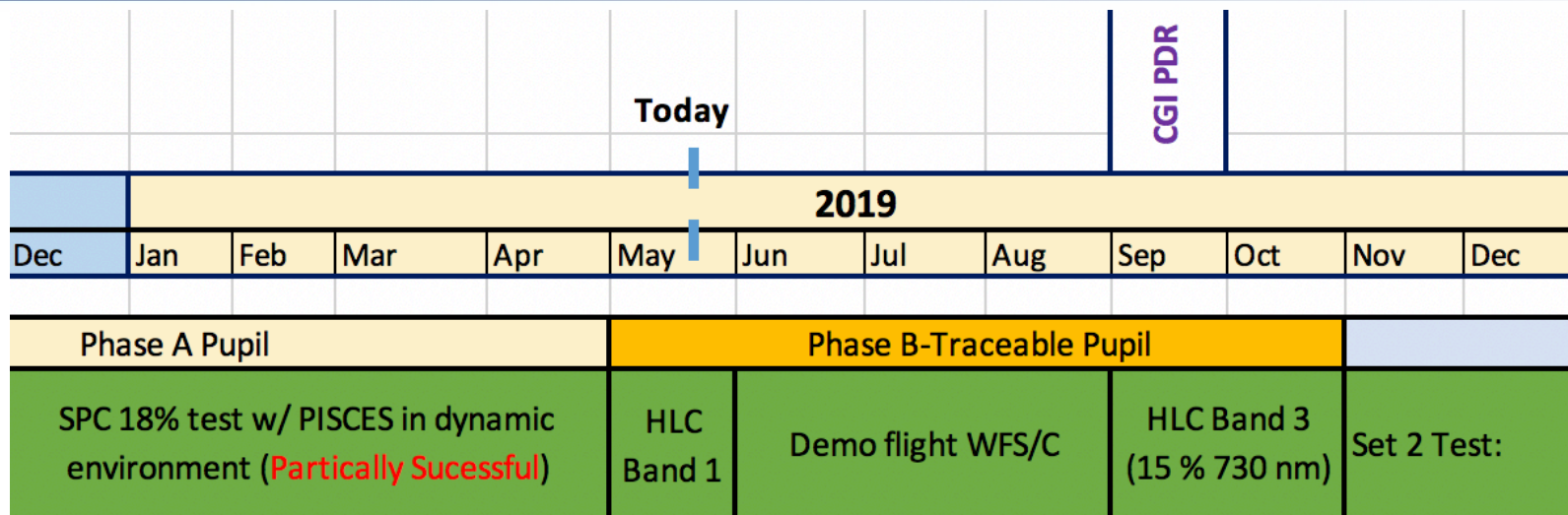
Cleared : URS281033

- **Testbed Schedule**
- **Testbed Status**
  - PISCES Test Result
  - LOWFS Test Result
  - Progress on Band1 (HLC 10% 575 nm) on Phase B pupil
- **Testbed Plan before PDR**



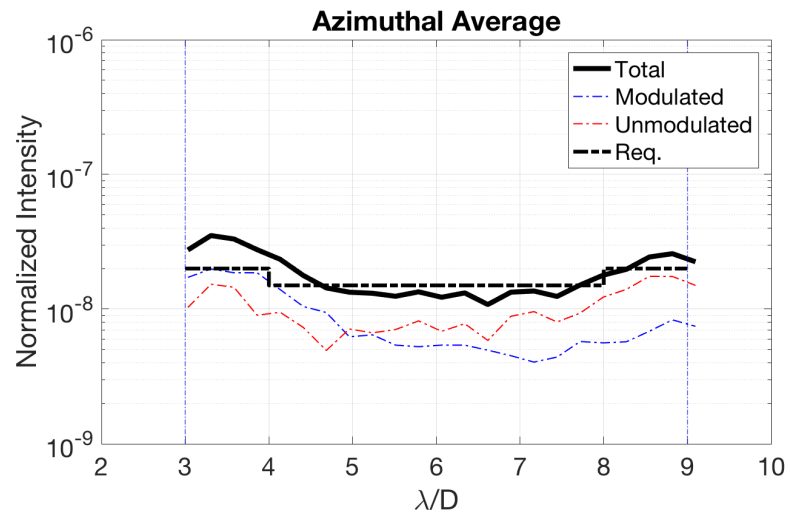
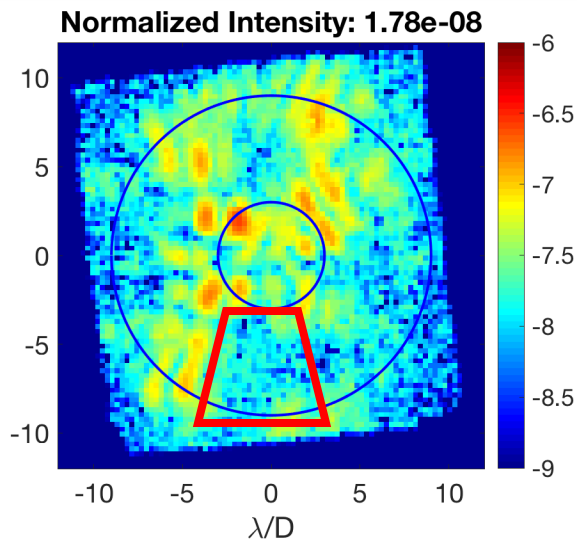


# CGI Tech Testbed Milestone in CY'19



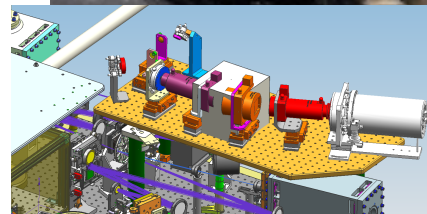
Milestones	Risk ID Addressed	Milestone Date	Status	Comments
SPC 18% Test w/ PISCES in Dynamic Environment	7, 8	04/12/2019	<b>Partial Success</b>	Could not meet the Raw contrast requirement. Successful LOWFS demo on OS6 multitone with 20 Hz feedback.
HLC Band 1 (10% 575 nm) in Phase B WFIRST pupil	21	05/17/2019	<b>In progress</b>	We test two candidate designs for Band 1 flight-baseline. We validate SPC using model. (No testbed demo of SPC on Phase B.)
Demo flight WFS/C	26	07/17/2019 [08/15/2019]	<b>Establish Test plan</b>	Preliminary WFC demo for Ground/Flight change, validating the iteration # (Risk 26). Only in HLC mode.

# Recent PISCES Demonstration



- **DO NOT** meet the raw contrast requirement. Shown above is 760 nm 18 % half dark hole only.
- Observed discrepancy between DICam and PISCES on the upper dark hole region.
- Contamination is identified as a potential source (Right image). No WFE calibration mechanism such as Phase Retrieval is available.
- Stray light dominates the bottom dark hole.

One of optics inside PISCES shows sign of contamination



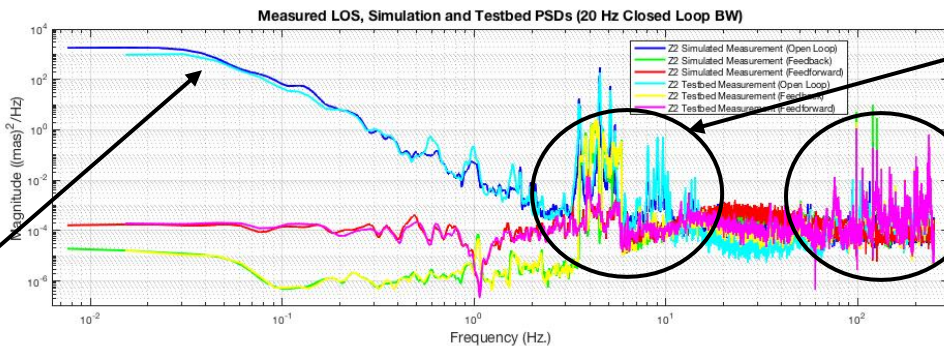




# LOWFS/C on OS6 Multitone Disturbance

Measured/Simulated  
PSD for Z2.  
(Similar story for Z3)

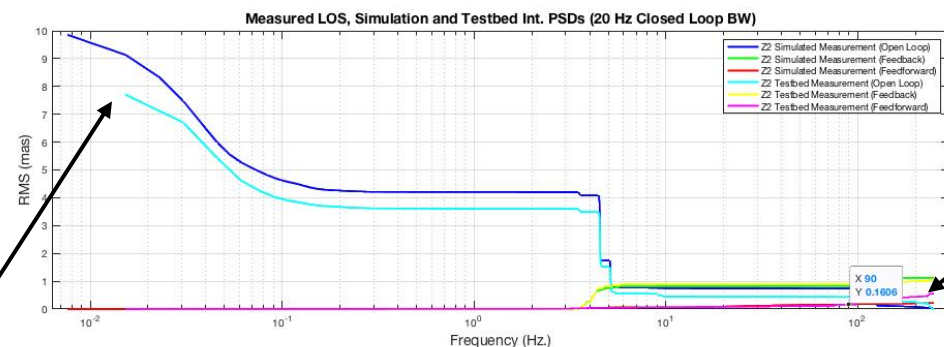
ACS drift injected



RWA tonal components  
and harmonics (caused by  
saturation nonlinearity of  
the LOWFS sensor)

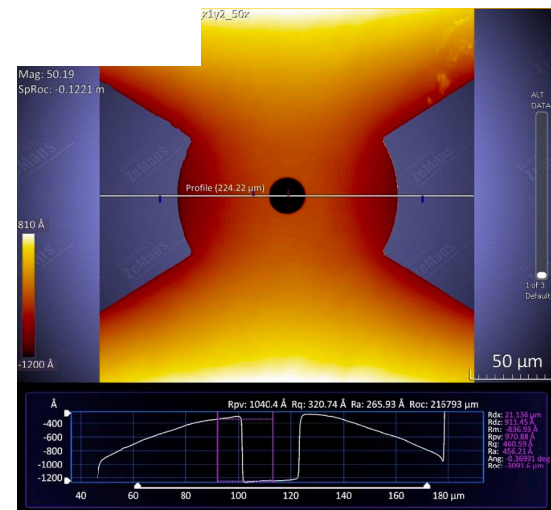
Testbed Environment

Accumulated RMS



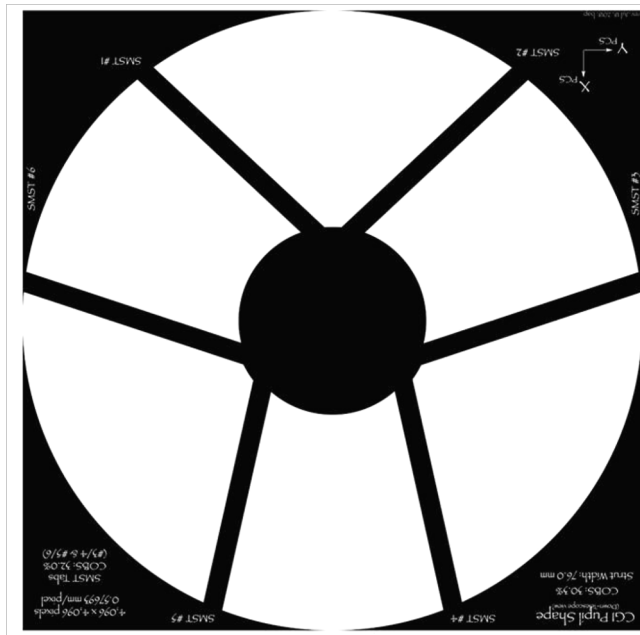
161 uas with FB and FF!

- Injected 8 mas OS6 ACS drift/RWA tonal components with 6 wheel phase and 6 wheel speed estimates (Req. 8 mas RMS, CBE 4 mas RMS)
- Achieved < 150 uas RMS/Axis up to 90 Hz with 20 HZ feedback control.
- Test is done using the HLC mask, not SPC bow-tie, due to 'bowing issue'. (~100 nm PV on the bow-tie. See figure right.)



# Phase B Pupil

Bitmap Input from GDFC



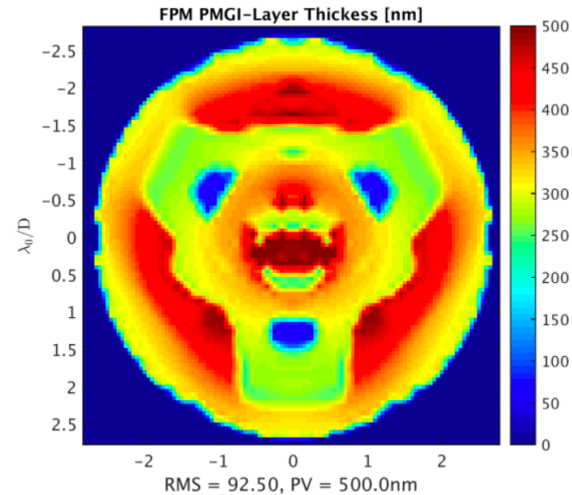
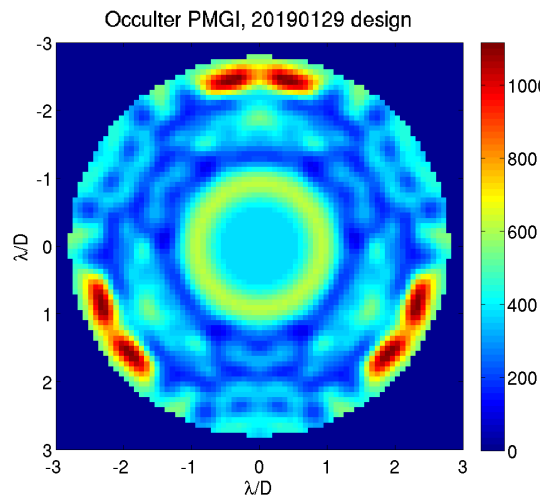
Microscopic image of fabricated Pupil before Testbed installation



- **Phase B Pupil**
  - Based on “Proposed official drawing of TCA exit pupil 20180718”; interpreted version of GDFC bitmap input.
  - Strut size is 3.22 % OD compared to 2.6 % of Phase A.
- **Fabricated Pupil agrees to the actual dimensions within 0.1% of OD.**

# New HLC Band 1 FPM Design

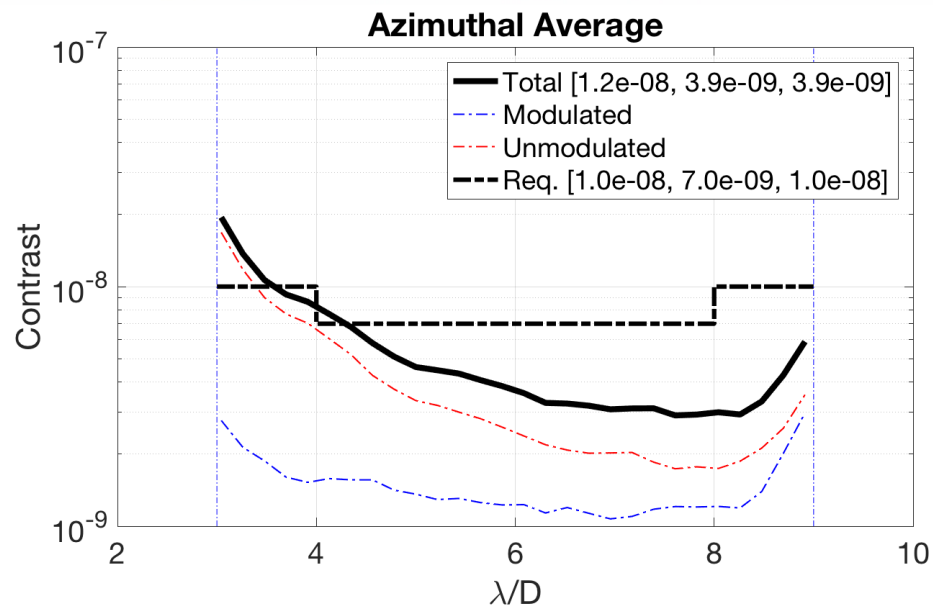
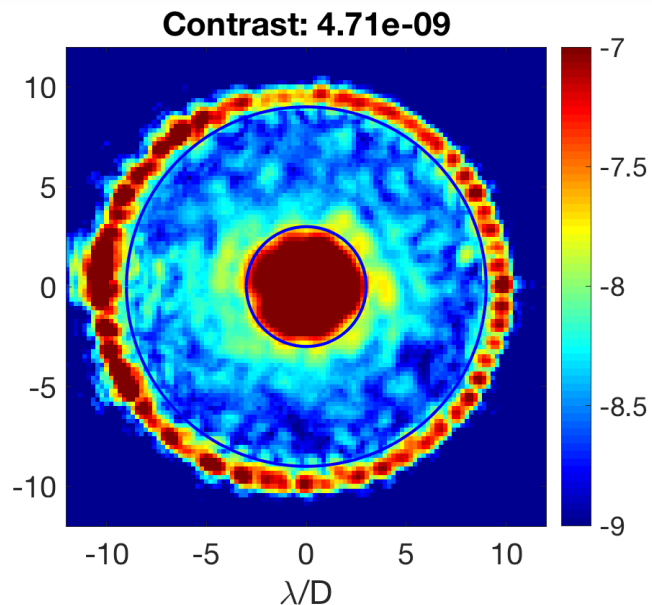
## PMGI shapes of Two designs



- Two new designs for Phase B pupil. Left is installed in testbed. Right is in fabrication.
- Asymmetric PMGI pattern from Design team to accommodate the thick struts.
- Currently aligned to Pupil by 1.11 degree.



# Current Best Result



- Meet the requirement except 3-4  $\lambda/d$ .
- Unmodulated light dominant:
  - 1.2E-8 unmodulated light measured in 3-4  $\lambda/d$  DOES NOT agree with estimation of 1.6E-9 based on testbed Jitter measurement + Tip/Tilt sensitivity measurement.
  - Either Pseudo-Star effect or Polarization.



# Near term goal: Optical Ground Parameter Search

- **Question: How can we obtain a good dark hole faster?**
- **Method:**
  - We have established a fully automated EFC routine: Baseline.
  - We vary one each parameter to track # of iteration, best contrast, throughput, Tip/Tilt sensitivity.
- **Period: By end of May.**

# Optical Ground Parameter Search

## Table So far

	Test	NOTE	Best iteration	# of iteration s	Best Contrast [3 region] $\times 10^{-9}$	Throughput (3 Ch value)	Tip/Tilt Sense (3 Ch value)
-1	15 % Small Region (IFS)						
0	Preliminary Run (3/5 Ch)	501-715 720-7xx	768		[12, 4.2, 4.7]	N/A	N/A
1a	Baseline (aggressive beta)	1001-1195	1195	195	[13, 4.7, 6.6]	N/A	x[1.6, 1.1,1.1] y[1.4, 1.0,1.0]
1b	Baseline	1501-1784	1783	284	[16, 5.0, 1.1]	Data in process.	x[1.7, 1.2,1.3] y[0.9, 0.6,0.6]
2	Bare NI	2001-					
3	Staring with Dwight Sol.						
6	R3C4 (some defect)						
5	Staring with Chromatic epup						
4	Change DM gain to 1						
7	Beta bumping 5/5 combination						
8	Occulter mask Resampling						
	Baseline (Repeated test)						





# Ground/Flight WFC Demo

- **Goal: Before PDR, we demonstrate the Ground/Flight WFC in Tech. Testbed.**
- **Major questions to answer in this test.**
  - Does Band 1/HLC meet the raw contrast requirement for Phase B pupil without computing power and time constraint?
  - Does Band 1/HLC meet the raw contrast requirement during commissioning in orbit after the planned WFC scheme provided by HOWFS/SE is applied?
    - Validate required # of iterations to support the 150 hr time allocation.
    - Low flux test or dynamic demo is desired but NOT required before PDR.
  - Does Band 1/HLC meet the raw contrast requirement after coronagraph mode changes with the planned WFC scheme provided by HOWFS/SE is applied?
    - Validate required # of iterations to support the 30 hr time allocation.
    - Low flux test or dynamic demo is desired but NOT required before PDR.
- **NOTE**
  - We are mostly concerned with “What & How we can implement the Ground/Flight Delta in the Tech. Testbed”. Next page tabulates our plan, which needs attention from SE.
  - The better/complete test shall be formed later in ETB. (ETB is not descoped.)



# Ground/Flight Delta implemented in Tech. Testbed

	Delta ID	Target delta	Req. (TTB equivalent)	Testbed Implementation	NOTE
OTA Change	1	OTA WF Phase	CBE OTA WFE (Appendix)	Switchable between a FM (Ground) and shaped OTA mirror (Orbit) at SP Mask.	The FA in TTB is off-axis, introducing non-flight-relevant issue.
	2	OTA WF Amplitude		Postponed to ETB. Model Study before PDR.	Expected small.
	3	OTA Chromaticity	TBD	Postponed to ETB.	Poor understand. May not be flight-relevant
	4	OTA Polarization-Dependent WFE	TBD	Postponed after PDR. Model Study before PDR. Add DST Result.	Use 'old' OTA-S after PDR. See page 14
OTA Alignment	5	OTA EnP lateral misalignment	+/- 0.1 % of pupil/axis (or +/-46.3 mm/axis)	translate pupil mask.	Non-flight mode: just translating pupil mask vs. actual pupil translation
	6	OTA EnP clocking misalignment	+/- 4 mrad	Make the second mask, scaled with 46.25 mm. Mount it with 4 mrad clocked. Switchable between the nominal/the second mask. This allows us to implement translation.	Need or modify the mechanism
	7	OTA EnP magnification	+/- 0.1% of OD (or 46.2537/46.3463 mm)		
	8	DM Hysteresis	TBD	Both DMs are zeroed for 2 (TBD) hours and turned on.	
Other	9	CGI internal misalignment	TBD mas/axis (or TBD um/axis)	Change source position x/y by TBD	

- Gray: NOT tested before PDR.



# WFIRST Testbed Demonstration History

Year	Accomplishment	Best Contrast	Testbed	NOTE
2015	Narrowband 360° HLC contrast demonstrated with WFIRST pupil and 2 DMs	$6.92 \times 10^{-9}$ @ 550nm, 3-9 $\lambda/D$	HCIT2	MS4 Report
2015	Broadband (10%) HLC contrast demonstrated	$8.54 \times 10^{-9}$ @ 550nm, 10 %, 3-9 $\lambda/D$	HCIT2	MS5 Report
2015	Broadband (10%) SPC contrast demonstrated	TBD@ 550nm, 10%, 3-9 $\lambda/D$	HCIT2	MS5 Report
2017	Broadband (10%) SPC/HLC contrast demonstrated in dynamic OMC testbed & model validation	$1.60 \times 10^{-9}$ @ 550nm, 10%, 3-9 $\lambda/D$	HCIT1 (TTB)	MS9 Report
2017	PISCES (18%) contrast demonstrated	$1.00 \times 10^{-8}$ @ 660nm, 18 %, 3-9 $\lambda/D$	HCIT2	
2018	Broadband (10%) Disc contrast demonstrated	$1.00 \times 10^{-8}$ @ 660nm, 18 %, 3-9 $\lambda/D$	HCIT2	
2019	PISCES (18%) contrast demonstrated	$2.xxx \times 10^{-8}$ @ 760nm, 18%, 3-9 $\lambda/D$	HCIT1 (TTB)	



# Backup

# Delta 1: OTA WF Phase Change

Delta ID	Target delta	Req. (TTB equivalent)	Testbed Implementation
1	OTA WF Phase	CBE OTA WFE (Page 6)	Switchable between a FM (Ground) and shaped OTA mirror (Orbit) at SP Mask.
2	OTA WF Amplitude		Postponed to ETB. Model Study before PDR.

Switchable between a FM (Ground) and shaped OTA mirror (Orbit) at SP Mask.

Postponed to ETB. Model Study before PDR.

IFS Legs (1 of 3)

Science Camera

LOWFS Camera

Focal Plane Mask

Shaped Pupil Mask

60" OAP

Pupil Mask

Source Stage

OAP #2

JM

FSM

OAP3

FM1

FA

OAP1

OAP2

OAP4

OAP5

OAP6

FM5

FM4

FM3

FM6

FM7

FM2

DM2

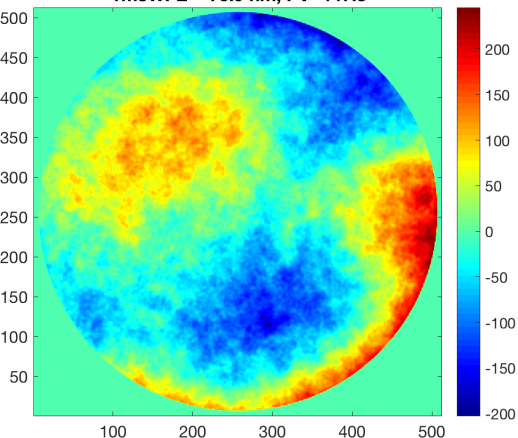
DM1

DM Elex Interface Boards

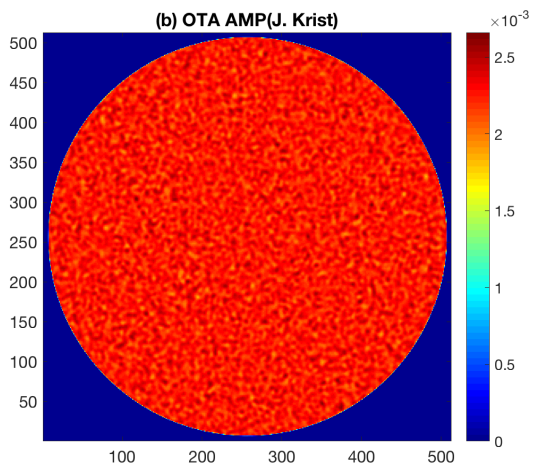


## & Proposed Mirror Shape

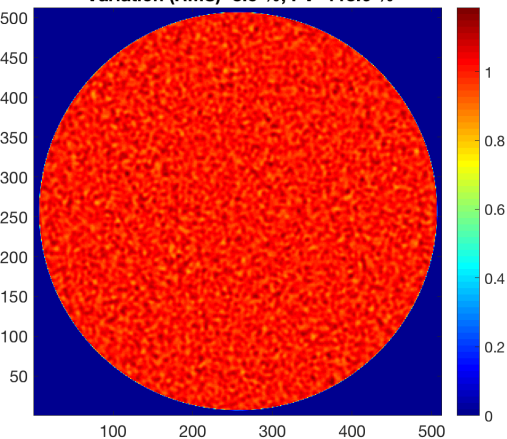
(a) OTA WFE (J. Krist)  
rmsWFE = 73.9 nm, PV=447.8



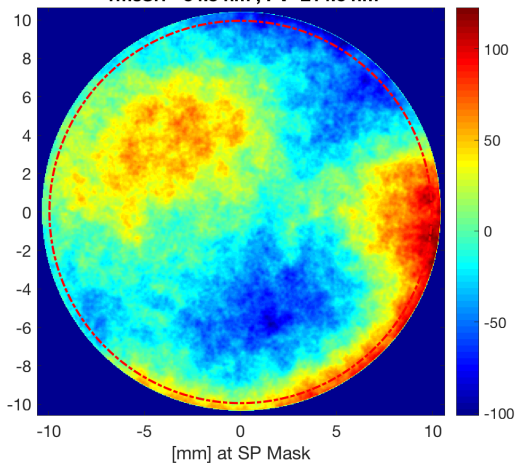
(b) OTA AMP(J. Krist)



(c) AMP normalized to mean  
Variation (RMS)=8.5 %, PV=118.6 %



(d) Propose Mirror Surface  
rmsSrf =34.8 nm , PV=214.3 nm



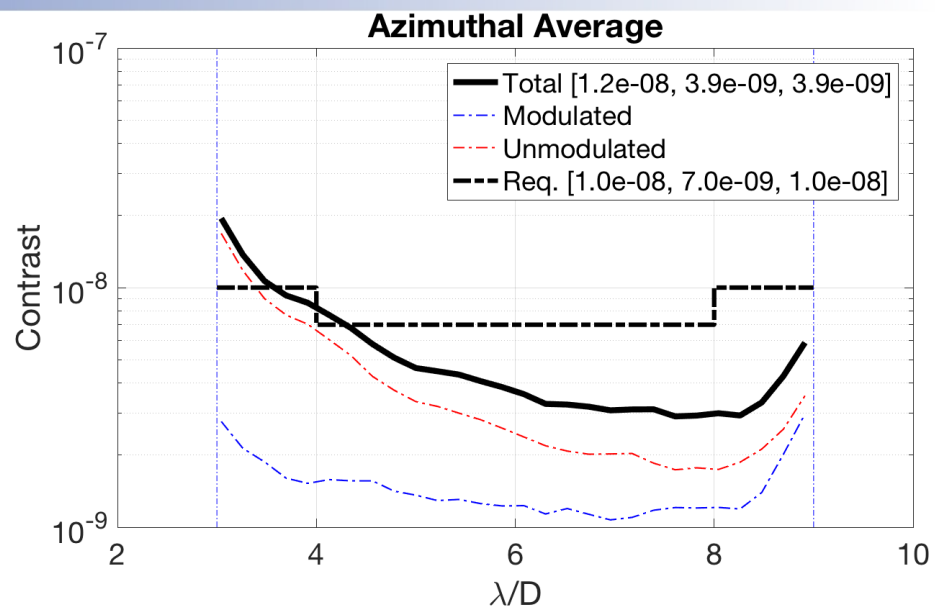
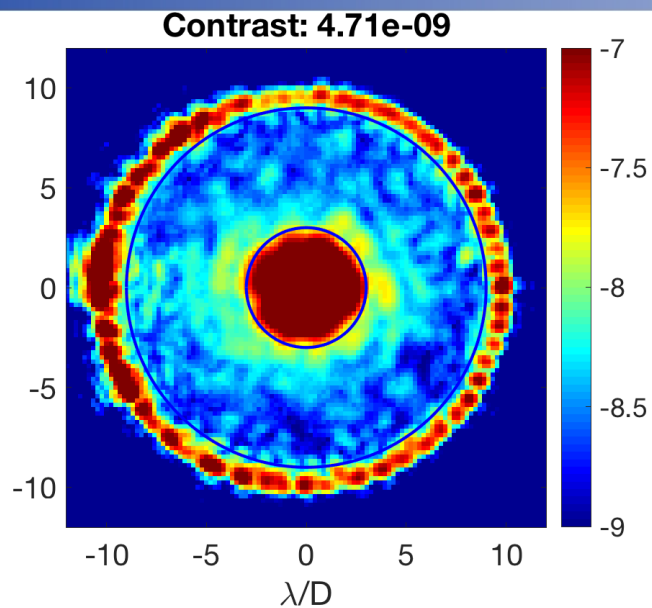
← Interchangeable with a flat at the SP Mask (We will replace the SPC mask with this.)

- Flat for Ground
- This mirror for in-orbit

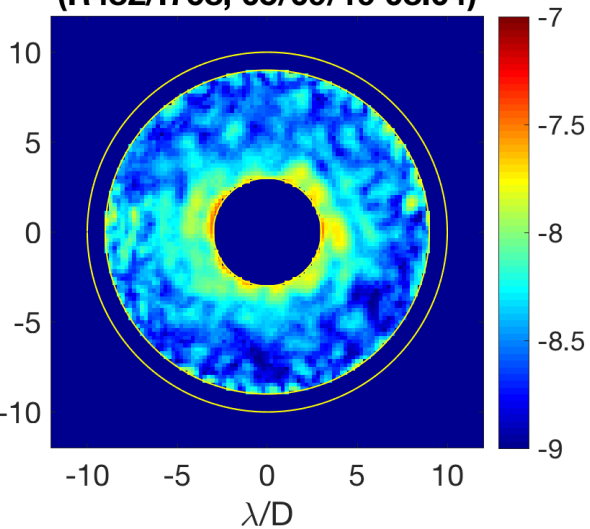




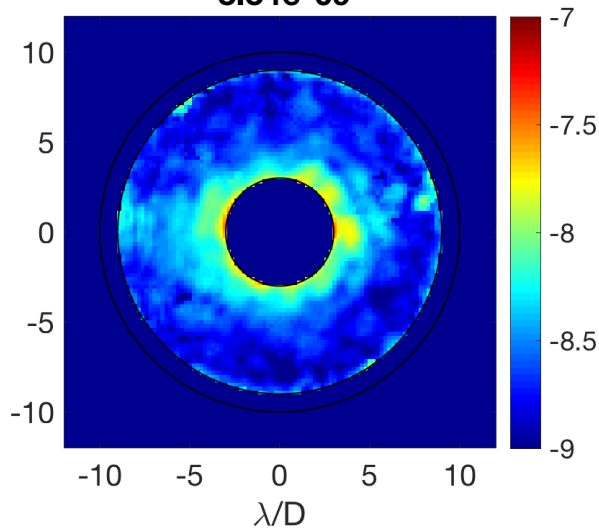
# Current Best Result



**Scoring Region**  
(R482/I768, 05/09/19 08:04)



**Unmodulated**  
**3.34e-09**



**Modulated**  
**1.45e-09**

